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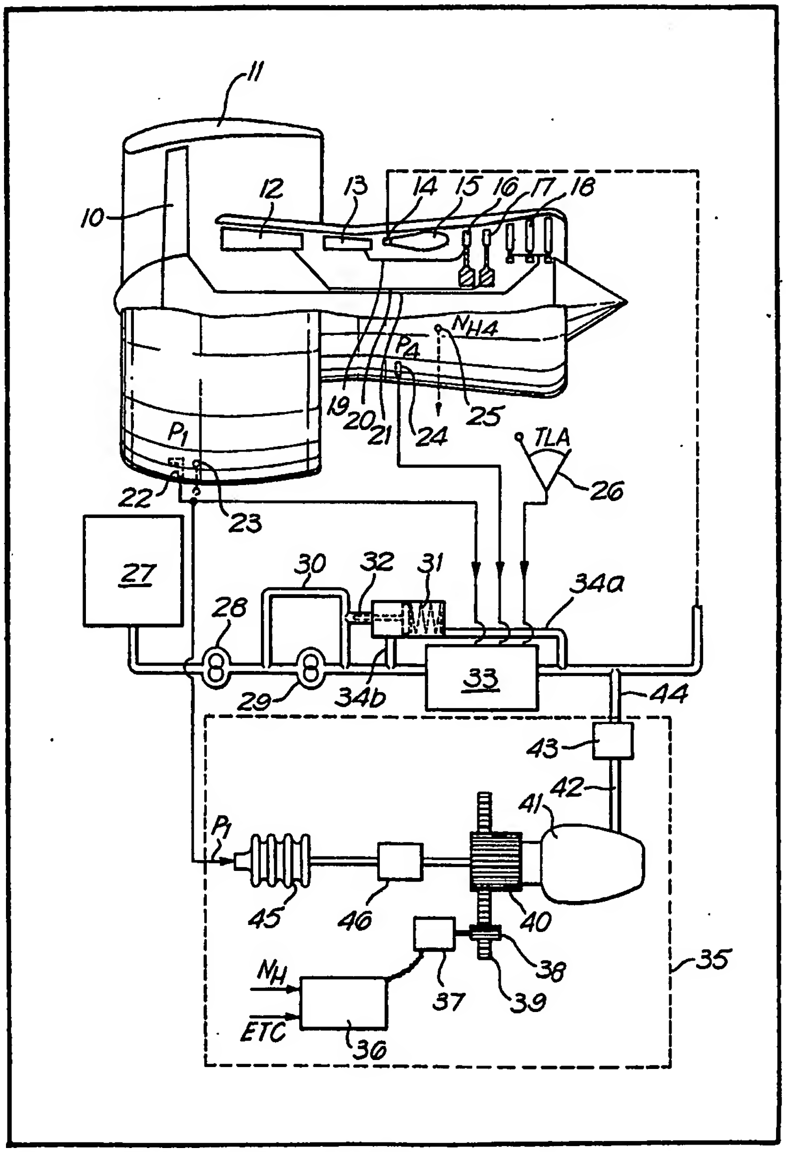
(54) Fuel Control System for a Gas Turbine Engine

(57) The system comprises a main controller (33) and an overspeed limiter (35) which provides a fail-safe should failure of the main controller (33) lead to an otherwise uncontrolled increase in fuel flow to the engine. In order to allow the limiter to reduce a maximum fuel flow to that required for safe operation at high altitude, while avoiding the possibility of a downward failure of the limiter at low altitude shutting the engine down, an input proportional to ambient pressure is used to control limiter operation. In the illustrated embodiment the ambient pressure input moves a three-dimensional cam (41) axially, the input dependent upon the speed of the engine rotor rotates the cam, and the output of radial motion of a follower (42) operates a fuel valve (44).



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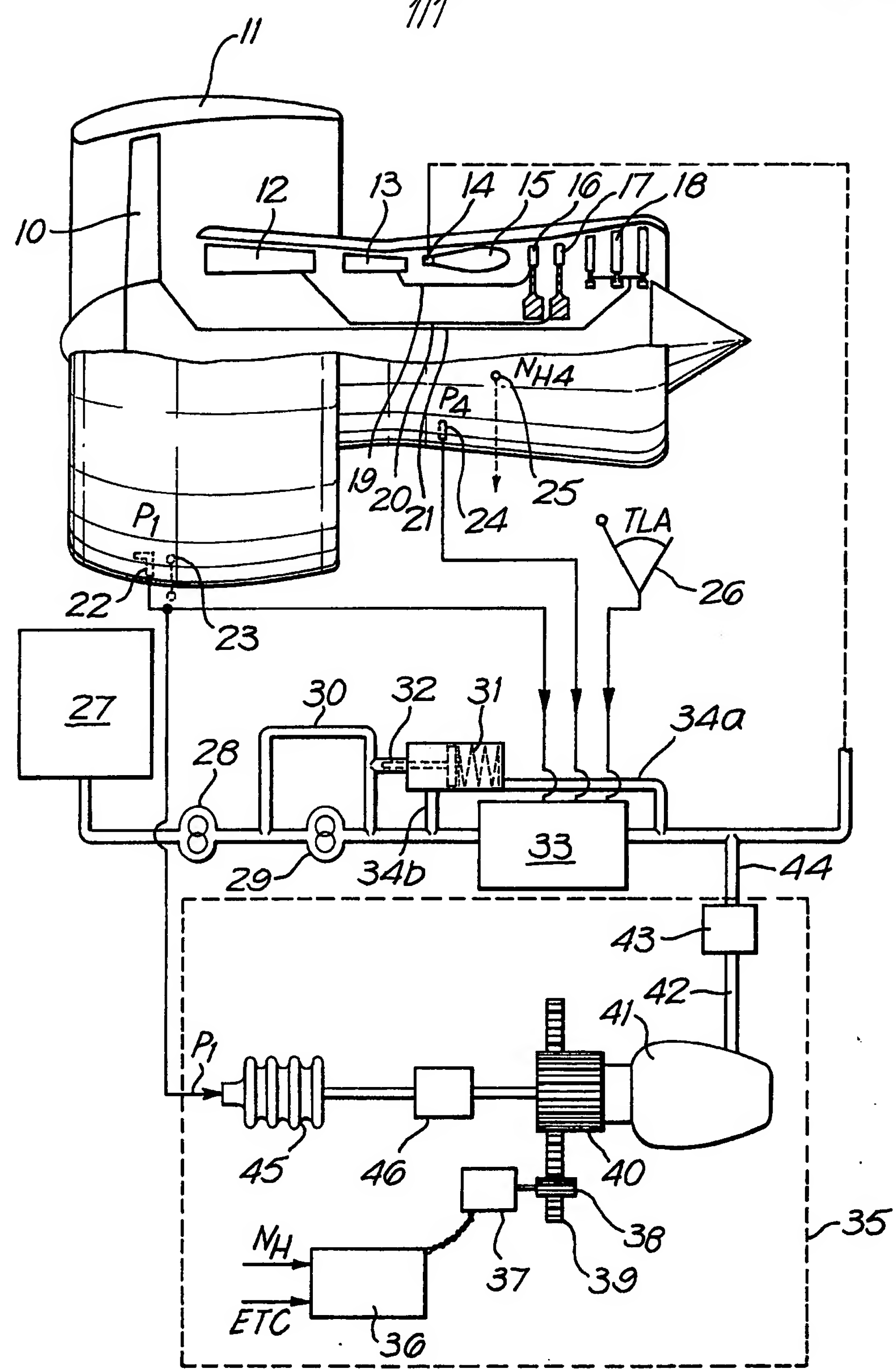
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SPECIFICATION

Fuel Control System for a Gas Turbine Engine

This invention relates to a fuel control system for a gas turbine engine.

It has in the past been common practice to incorporate in such fuel control system an overspeed limiter. This device is arranged to detect the speed of a rotor (normally the high pressure rotor) of the engine and to reduce the fuel flow if the design speed is exceeded. The use of these limiters ensures that no single failure within the fuel system can allow the fuel flow to be uncontrolled, leading to possibly dangerous overspeed of the engine.

It is a characteristic of the gas turbine engine that its thrust decreases with decrease in air density and consequently with increase in altitude. Therefore the difference between the safe fuel flow and the maximum possible fuel flow to the engine will vary from being relatively small at sea level to being considerable at altitude. The overspeed limiter must have the capability of reducing the fuel flow from the maximum to a safe value, therefore a limiter which is capable of dealing with a high altitude failure must be able to influence the fuel flow quite considerably (this is known in the art as having 'large authority').

This therefore gives rise to the possibility that a failure of the limiter at low altitude could cause the fuel flow to be reduced below a safe operating minimum.

The present invention provides a limiter whose capability for reducing the fuel flow is made ambient pressure dependent, and thus the chances of such a catastrophic failure are reduced.

According to the present invention a fuel control system for a gas turbine engine comprises a main controller and an overspeed limiter for reducing the fuel flow to the engine if an engine rotor speed exceeds a predetermined limit, the amount by which the limiter can reduce the fuel flow being dependent upon the ambient air pressure.

In one embodiment the limiter operates a fuel valve in accordance with the output of a three-dimensional cam device, the inputs to the cam being proportional to the ambient pressure and the engine rotor speed in question. Thus the axial displacement of the cam may be proportional to the ambient pressure, the rotational displacement proportional to the rotor speed, and the output of radial displacement of follower used to control the fuel flow.

The basic rotor speed control of the limiter may be varied in accordance with other variables, and clearly it is easier to use an electronic device to integrate these variables in a suitable manner before using the modified variable to operate the limiting function.

The controller may be of any of the conventional kinds.

The invention will now be particularly described, merely by way of example, with reference to the accompanying drawing which is a diagrammatic view of a gas turbine engine having a fuel control system in accordance with the invention.

In the drawing there is shown a gas turbine engine which in the present instance is a three-shaft front fan engine. The principles of operation, of these engines are well-known, but for completeness the operation is briefly set out below.

The engine comprises a fan 10 operating within a fan cowl 11 and compressing air part of which provides forward thrust and part of which acts as the intake air for the remainder of the engine. Air entering the remainder of the engine is compressed by the intermediate pressure and high pressure compressors 12 and 13 in sequence, and is then mixed with fuel supplied by a fuel injection system 14 the resulting mixture being burnt in a combustion chamber 15. The resulting hot gases drive the high pressure, low pressure and fan turbines 16, 17 and 18 in series and exhausts through a nozzle to produce additional propulsive thrust.

Each of the turbines 16, 17 and 18 is drivingly connected with its respective compressor 10, 12 and 13 by respective shafts 19, 20 and 21 to form fan, intermediate pressure and high pressure rotors of the engine respectively. Various transducers are provided to enable parameters of the engine to be detected, and in particular the engine intake pressure P_1 is detected by a transducer 22, the intake temperature T_1 detected by transducer 23, the compressor delivery pressure P_4 detected by transducer 24 and the rotational speed N_H of the high pressure shaft 19 (and thus of the high pressure rotor in general) is detected by the transducer 25.

Primary control of the thrust produced by the engine and of the various operating parameters is effected by a fuel control system responsive to the setting of a throttle lever 25 and to various parameters as measured by the transducers referred to above. The complete primary fuel system in the present case withdraws fuel from a tank 27 via a low pressure pump 28 and a high pressure pump 29. A bypass passage 30 round the pump 29 is controlled by a piston and cylinder 31 which operates a valve 32.

Fuel from the pump 29 flows into a primary fuel control unit 33. The unit 33 has controlling inputs from the throttle lever 26 and the transducers 22 and 24, and thus controls the fuel flow in accordance with the setting of the throttle lever and the overall pressure ratio P_4/P_1 of the engine. It will be understood that various devices could be used to carry out this function; one such device is described in our British Patent 1,135,614. However, it is clear that various conventional fuel controllers, be they all hydromechanical, hydrochemical supervised by an electronic trimmer, or all electronic (analogue or digital) could be used to carry out this function.

Whatever its internal construction, the effect of the fuel control unit 33 is to vary the fuel flow into

the fuel injection system 14 so as to produce from the engine an amount of thrust which meets as closely as possible the demanded thrust set on the throttle 26. A passage 34a allows the pressure of fuel downstream of the unit 33 to act on one side of the piston of the piston and cylinder 31, while a second passage 34b allows the pressure of fuel upstream of the unit to act on the other face of the piston. It will be appreciated that if the unit 33 allows more flow to take place, the pressure in the passage 34 will increase and cause the piston and cylinder 31 to close the valve 32 and reduce the spill flow in the bypass passage 30, allowing a greater part of the flow of the pump 29 to flow to the fuel injection system. The piston and cylinder device 31, valve 32 and bypass passage 30 provide a means by which the gear pump 29 need not have a variable delivery but is still enabled to provide a varying flow of fuel to the injection system.

The system described so far is conventional, and will provide satisfactory control of the engine under normal conditions. However, if the fuel control unit 33 should fail, there may be a danger that it could fail 'upwards' that is that it will allow a maximum, unrestricted fuel flow to the engine. Although this may be a very unlikely event, the very high standards of safety required of gas turbine engines in their aero application may require that a back-up be provided to cater for this kind of upward failure.

The embodiment illustrated therefore includes an overspeed limiter generally indicated at 35. This basically consists of an electronic limiter 36 having inputs of at least N_H and in some cases other parameters, which produces an output signal if the high pressure rotor speed N_H exceeds a predetermined value, or a predetermined value which takes into account the other parameters.

The output signal from the electronic limiter 36 is used to operate a motor 37 which drives a rack 38 via a pinion 39. The rack 38 in turn rotates a further pinion 40 carried on the base of a three-dimensional cam 41. Rotation of the cam 41 by the pinion 40 causes a radial motion of the cam follower 42, which actuates a position servo 43 to operate a throttle valve 44. It is arranged that should the speed N_H exceed the predetermined value the limiter 36 will cause the motor 37 to rotate the cam 41 and thus partially close the valve 44.

In order to prevent the engine being completely shut down by the valve 44 it is only enabled to reduce the fuel flow to the engine by an amount sufficient to reduce a maximum fuel flow to a value at which the engine can run safely. However, in the case of high altitude operation the required fuel flow will be very low, and the valve 44 must be able to reduce the fuel flow from a maximum to this very low value.

If we now consider whether the limiter 35 is itself safe under fault condition, it is clear that the most dangerous fault would be a 'downward' failure of the limiter, i.e. one where the limiter causes the valve 44 to close to its maximum extent. If the fault occurs at high altitude there is no danger because the fuel flow allowed by the valve 44 will suffice for the engine to continue operation. However, if the fault occurs at low altitude the fuel flow allowed by the valve 44 when shut down to its high altitude value may not suffice to enable the engine to continue to operate.

To deal with this problem the limiter 35 in the present invention is provided with an input from the transducer 22 proportional to P_1 the intake pressure, and this pressure is arranged to vary the amount by which the valve 46 can be closed so that it will always be sufficiently open to allow the engine to operate. To do this, the input (shown as the actual pressure P_1) operates a bellows 45 which causes a position servo 46 to move the three-dimensional cam 41 axially. It can be arranged that the shape of the cam is such as to give the relationship

$$\text{Fuel flow} \propto \text{valve 44 position} \propto P_1 \times \text{electronic limiter output}$$

Clearly if P_1 increases, as the altitude decreases, the fuel flow allowed for a given limiter output will also increase. Therefore if some failure causes the limiter 36 to provide an output to close the valve 44 right down, the effect of the P_1 input will be such as to prevent the closure of the valve below a setting at which engine operation is satisfactory.

If the main fuel controller fails upwards, the limiter with the P_1 input described will still be able to control the valve 44 to provide a safe engine speed. It will be seen that the invention therefore provides a way in which satisfactory normal operation of the limiter is retained but the effect of a failure of the limiter itself is mitigated.

The embodiment described above will be seen to use a mechanical device for improving the P_1 input on the limiter output and an electronic device to calculate the N_H related input. This is a particularly suitable combination, since the electronic device is better able to produce the necessary output from a plurality of inputs but may be less reliable, while the mechanical arrangement for applying P_1 is very reliable so that the chances of a failure of both items is remote.

However, it will be appreciated that there are a number of ways in which the ambient pressure compensation of the invention could be applied; for instance a totally electronic or totally mechanical system could well be used.

It should also be noted that in a multi-shaft engine of the type illustrated it may be desirable to have separate limiters each operated in response to the speed of one of the shafts.

Claims

1. A fuel control system for a gas turbine engine comprising a main controller and an overspeed limiter for reducing the fuel flow to the engine if an engine rotor speed exceeds a

predetermined limit, the amount by which the limiter can reduce the fuel flow being dependent upon the ambient air pressure.

2. A fuel control as claimed in claim 1 and in which said limiter operates a fuel valve in accordance with the output of a three-dimensional cam device, the inputs to the cam being proportional to the ambient air pressure and said engine rotor speed.

3. A fuel control system as claimed in claim 2 and in which the axial displacement of the cam is proportional to the ambient pressure, the rotational displacement of the cam is dependent upon the engine rotor speed, and the output of radial displacement of a cam follower is used to actuate said valve.

4. A fuel control system as claimed in claim 2 or claim 3 and in which said input to the cam proportional to the ambient air pressure is made by a hydromechanical device.

5. A fuel control system as claimed in claim 3 and claim 4 and in which said hydromechanical device comprises a bellows responsive to the ambient air pressure connected to actuate a position servo which in turn varies the axial position of the three-dimensional cam.

6. A fuel control system as claimed in any one of claims 2 to 5 and in which said input to the cam proportional to the engine rotor speed is made by an electronically controlled motor drive.

7. A fuel control system substantially as hereinbefore particularly described with reference to the accompanying drawing.

8. A gas turbine engine having a fuel control system as claimed in any one of the preceding claims.

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